Technology Prediction Is Never Well Received

"There is no likelihood man can ever tap the power of the atom."
Robert Millikan, Nobel Prize in Physics, 1923

"The energy produced by the breaking down of the atom is a very poor kind of thing. Anyone who expects a source of power from the retransformation of these atoms is talking moonshine."
Ernest Rutherford

"While theoretically and technically television may be feasible, commercially and financially I consider it an impossibility, a development of which we need waste little time dreaming."
Lee DeForest, 1926

"There has been a great deal said about a 3,000 mile rocket. In my opinion such a thing is impossible for many years. I say technically I don't think anyone in the world knows how to do such a thing and I feel confident it will not be done for a very long period of time. I think we can leave it out of our thinking."
Vannevar Bush, Testimony to Senate December, 1945

"What, Sir? Would you make a ship sail against the wind and currents by lighting a bonfire under her deck? I pray you excuse me. I have no time to listen to such nonsense."
Napoleon to Robert Fulton

"There is no hope for the fanciful idea of reaching the moon, because of insurmountable barriers to escaping the Earth's gravity."
Dr. F. R. Moulton, astronomer University of Chicago, 1932

"Everything that can be invented has been invented."
Charles H. Duell, Director of U.S. Patent Office, 1899

"That is the biggest fool thing we have ever done . . . The [atomic] bomb will never go off, and I speak as an expert in explosives."
Adm. Wm. Leahy to President Truman, 1945 (Presumably prior to 6 August)

"Rail travel at high speeds is not possible because passengers, unable to breathe, would die of asphyxia."
Dr. Dionysys Ladner (1793–1859)

"We must not be misled to our own detriment to assume that the untried machine can displace the proved and tried horse."
Maj. General John K. Herr, 1938

Siegfried_11_01_01 2

BOEING

Several Of Us Shared Ideas

- Brian Tillotson
- Thomas Austin
- Stan Schneider
- Ed McCullough
- Harvey Willenberg

Key Technology Requirements – *Today's Thoughts*

Robotic Missions	Human Near-Term Lunar	Human Extended Lunar	Human Earth/Sun Libration Asteroids	Human Mars
Aero braking (Earth/Mars)	(Solar Electric Propulsion)	In Situ Resource Utilization	Human/Robotic Interaction	Zero g Research & Countermeasures
Autonomous Rendezvous & Capture	Crew Systems	Surface Habitats	Space Repair & Maintenance	Advanced Propulsion (Nuclear/VASMIR) (Solar Electric)
Radioisotope Stirling Cycle Converter	High-Performance Space Chemical Propulsion	Radiation Protection	Solar Electric Propulsion	Heavy Lift Earth Orbit Transportation
Autonomous Operations	Space Habitation Systems at Lagrange	Regenerative Closed-Loop Life Support	Regenerative Closed-Loop Life Support	In Situ Resource Utilization
Solar Electric Propulsion	Advanced Life Support (Minimum Resupply)	Robust/Efficient Surface Power (Solar)	Aeroassist at Earth Return	Regenerative Closed-Loop Life Support (Plant Growth)
High-Rate Data Compression & Transmission	Lunar Transfer Systems (Landing & Return)	Human/Robotic Interaction	Long-Term Chemical Propulsion	Human Robotic Interaction
Micro/Nano Electronics	Aeroassist at Earth Return	Robotic Exploration Systems	Crew Modules	Advanced EVA/Surface Mobility
Radiation-Tolerant Systems	EVA Suits	EVA & Surface Mobility	Radiation Protection	EVA Suits
Lightweight/Autonomous Rovers	Solar Power	Cryo-Propellant Manufacturing & Storage	Zero g Research & Countermeasures	Science Systems
Data Relay Systems (GPS-Like)	Radiation Warning	Orbital & Surface Navigation	EVA Suits	Radiation Protection
Planetary Protection (Both Ways)		Aeroassist at Earth Return		Power Systems (Radioisotope Stirling Cycle Converter)
Precision Landing		EVA Suites		Radiation Protection
		Radiation Warning		Autonomous Operations
				Health & Psychology
				Navigation/Data Relay Systems

Mars Sample Return – Required Technology Demonstrations - *15 Key Needs*

Subsystem Elements

- Solar electric thrusters
- Radiation-hardened systems
- Trajectory control (autonomous low-thrust navigation)
- Stirling cycle converter
- Autonomous rendezvous and capture
- Sample Selection and Handling
- Drill
- MEMS IMU
- HAN-based monopropellant
- Lightweight UHF transponder
- Visual navigation sensor & Smart Lite Beacon
- Rendezvous and landing Lidar
- Autonomous surface operations
- Precision entry and landing
- Planetary protection testing

Mars Sample Return – Required Technology Development *Subsystem Performance Targets*

Item	Performance Resumed	Mass (kg)	Power Req (Watts)	Volume CC	Notes
N star thrusters	Max 92.7 Mn thrust lifetime 14,000 hours, Max Isp 3900sec	8.3	2900 Max		Requirement may not exceed DS-1 Flight Demonstration
MEMS IMU	1 deg/hr drift, Rad Hard	0.28	0.8	26	Shown on MAV may apply to other subsystems, similar to tactical system application
HAN water Glycine for HES	Isp 230 (200 Pulse), 20 ms minimum pulse, high thrust 325N, low thrust 15N	NA	NA	NA	Baselined for recovery safety on HES
VisNav Sensor	100 meters range/S/N .002	1	5	1500	On SEP
Smart Lite Beacon (per unit)	3 watts per cm² at 150M	0.1	1	200	Multiple units on MAV
Stirling cycle converter	4.2 W/kg 110w continuous heat reject 350W per $100W_e$	2.6	–		Dual converters heat control by radiators heat pipes during cruise
Drill	3 m length 1 m/hr rate bit & stem change out capability		55		Rover main unit
Miniaturized UHF Transceiver	10,000 km max 400 MHZ	1	10	100	MAV and SEP units
Rendezvous LIDAR and Landing Unit	1μm scanning mechanical scan	5	32	4000	Same basic unit assumed for both missions

Mars Sample Return – Emerging Technologies Applicable
Horizon Technologies For Baseline Improvement

Item	Benefit	Probability of Occurrence	Applicability	Heritage	Current TRL level
Lightweight/rollup high-efficiency solar cells	150 W/kg or better reduces system weight	Exist	1,3,4,6	AFRL, DARPA	7
Carbon/carbon structural radiators	40% weight reduction over aluminum	Exist	1,3,4	AFRL	7
High-efficiency batteries (sodium sulphur)	150 W/hr/kg at high operating temp	High	1,3,4,5,6	AFRL/SANDIA Naval Surface Warfare Center	7
Onboard autonomy	Reduced operations cost—rover operations	High	1,4,6	AFRL/DARPA NASA JPL (NMP)	5–6
Open architecture software	Reprogramming during mission	High—exist	1,2,4,5,6	DOD/DARPA NASA JPL (NMP)	5–6
Supersonic parachutes	Steerable, high-speed aerobraking	High	2	AFRL	3–4
Photonics	Reduce system avionics weight (20%) with 50–100% bandwidth increase	High	1,3,4,6,7	AFRL/DARPA Livermore	5 components 3 system
3U-CPCI repackaging	Up to 50% mass power and volume reduction	Medium	1,6,4		

Applicability: 1) Mars cruise, 2) Entry and landing, 3) Lander, 4) Rover, 5) MAV, 6) EP Stage, 7) science

Siegfried_11_01_01 7

BOEING

Advanced Space Technology Of The 21st Century

(Not in any order)

- Optical computers/quantum computing/biometric (DNA) computing
- Autonomous systems
- Human/computer interactive design/manufacturing
- Bio-electronics
- New materials (phase shifting, new alloys)
- “Holodeck” simulation systems—advanced virtual reality
- Vehicle/personnel noninvasive monitoring/failure detection/repair
- Energy beaming for transfer and propulsion
- Micro/nano technology systems
- Fusion systems (use of ^{3}He from moon)
- Super pressure effects on materials
- Genetic engineering for propellant generation/materials creation
- Ambient temperature superconductivity
  - Maglev, temperature control, radiation protection
- Particle (anti-particle) storage—anti-matter propulsion
- Photonics

Siegfried_11_01_01 8

BOEING

Near Term Development Within 10-20 Years

- Tethers in earth vicinity and in space
- Nano technology (structure/biological/electronic/computing)
- Indigenous materials use (lunar heavy metals/ construction/propellants)
- Bio/electronic computing
- Quantum computing/devices
- MEMS applications (GN&C/power/data processing)
- High temperature superconductors
- Mini-magnetospheric plasma propulsion
- RF-ION Cyclotron Thrusters (VASMIR)
- Energy beaming
- Autonomous operations/on site data analysis
- Holographic memory/terabite memory
- Photonics

Presently Conceivable Innovations Within 40 Years

- Biometric actuators/sensors
- Human-level intellect
- Telesurgery/telepresence
- Antimatter propulsion
- Force field machines (HTSD devices or electrogravitic systems)
- Quantum teleportation and communication (quantum entanglements)
- Fusion propulsion

Potential Physics Changes

- Fine-structure constant ($\propto$ migration)
- Space energy utilization
- Neutrino applications
- Super-light speeds
- Wormhole time travel

Siegfried_11_01_01 11

So What?

- Shorter trip times
- Humans as passengers using their cognitive abilities
- Robotic systems with human centered computing
- Machines as cognitive prosthesis (extension, not imitation)
- Holographic training
- Use of indigenous materials

Siegfried_11_01_01 12